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A PROGRAM FOR LISTING OF OGO ATTITUDE ORBIT TAPES

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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I. INTRODUCTION

The Program for Listing of Attitude Orbit Tapes was prepared in order to list orbit numbers and start and stop times of orbits on attitude orbit tapes that were produced for the Orbiting Geophysical Observatory (OGO) mission.

The OGO spacecraft employs an on-board Automatic Control System (ACS) to orient the observatory on sun-earth reference axes, position the solar array panels normal to the sun, and turn the Orbital Plane Experimenter Package (OPEP) into the direction of the spacecraft's velocity vector whose component is projected into the plane of the orbit. A digital computer program computes the attitude and the orbital position of the OGO spacecraft for later correlation with experimental data. The program produces attitude orbit tapes as an output and each OGO experimenter receives copies of it. During the lifetime of each OGO spacecraft a large number of attitude orbit tapes have been sent to each experimenter. Sometimes corrections and updates of tapes are also sent to each experimenter increasing the total number of tapes on hand. The large volume of tapes and the ordering of updated tapes created a need for cataloguing all available tapes. Therefore, a computer program was prepared to list all available tapes on hand and this information was sent to each OGO experimenter in order to establish and maintain a complete library of OGO attitude orbit tapes. The design of that computer program and its usage are described in this report.

II. OPERATING INSTRUCTIONS

Requirements

This program is executed as a regular job on a Univac 1107 or 1108 computer utilizing an EXEC II System. A typical run setup uses a minimum of two tape drives, the card reader, and the printer. An additional tape transport should be provided for tape swapping, if more than one attitude orbit tape is to be listed. Figure 1 shows the typical process flow of a run setup.

Input

Input consists of the following:

1. A run deck including a program control card

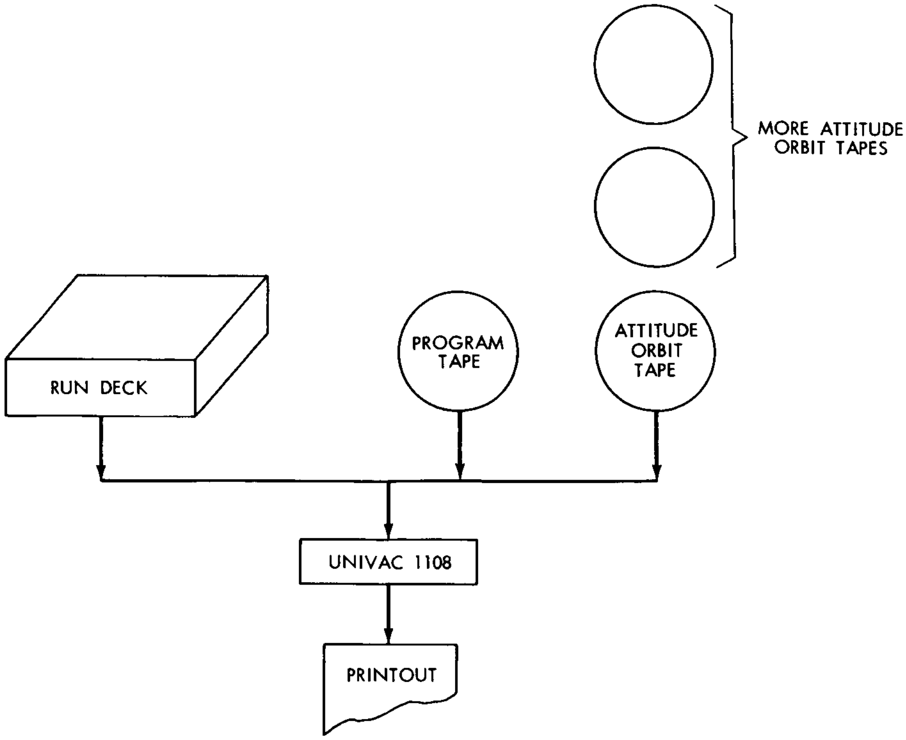


Figure 1. Process Flow Diagram

2. The program tape
3. OGO attitude orbit tape(s)

Run Deck—The run deck consists of EXEC II control cards and a program control card. The setup of the run deck is shown in Figure 2. The program control card contains the number of OGO attitude orbit tapes that are to be listed. The format of the program control card is as follows:

Column	Description	Type	Comments
1-5	Number of OGO attitude orbit tapes	I5	If blank, one tape is assumed

Output

A typical sample of the printed output listing is shown in Figure 3. A blank line signifies the end of a physical tape in this listing. A title page is also printed and all succeeding pages are numbered by the program for proper identification.

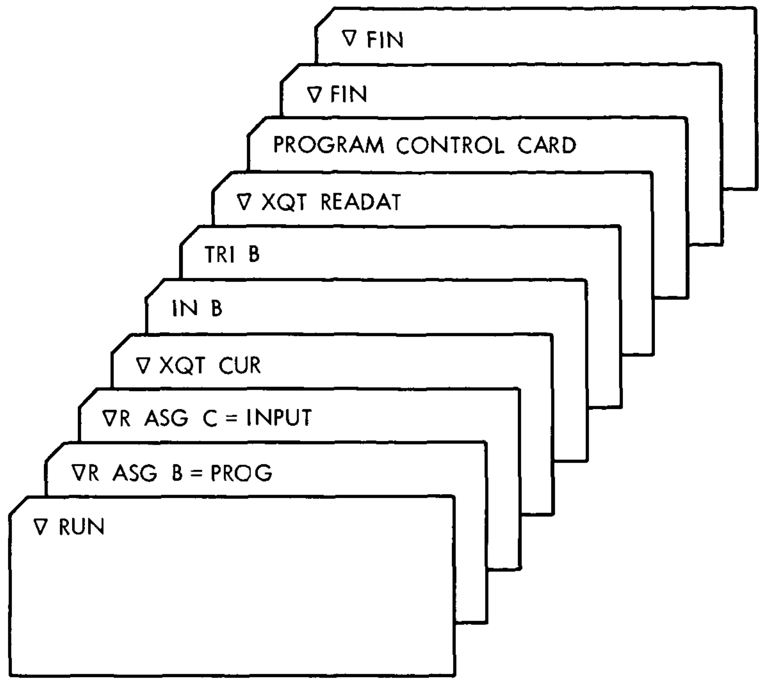


Figure 2. Run Deck Structure

III. PROGRAM DESCRIPTION

The execution of the program begins with the main program routine READAT. It prints the title page and initializes several internal program variables. Then the succeeding page number and a page heading is printed. A tape read buffer routine is initialized by calling READA which requires the following calling arguments: the logical tape transport number, the buffer area to be used by the routine, the number of words in each physical record, and the tape re-read option to be followed in case of a read error. READA begins the buffered tape reading by filling the buffer with the first record. The subsequent call READB transfers the buffer record into the data area and initiates the reading of the next physical record into the buffer area. After reading the label record in the file, the program reads the start time of an orbit from the first data record. The orbit number of the data file is also stored away. Each record in the file is read until the stop time of the orbit is found. The subroutines CONDAY and MILSEC are called prior to the printing of the orbit number and the printing of the corresponding start and stop times of the orbit. The subroutine CONDAY converts the day of year and the given year to a date in form of a Fieldata image of year, month, and day. This date is printed out in the listing of the start and stop times, and it improves the readability of the listing. The

ORBIT NO.		START TIME				STOP TIME			
	DATE	DAY OF YEAR	HR	MIN	SEC	DAY	HR	MIN	SEC
160	651103	307	3	47	60.	309	19	46	0.
161	651105	309	19	47	47.	312	11	44	0.
162	651108	312	11	45	43.	315	3	44	0.
163	651111	315	3	44	32.	317	19	45	0.
164	651113	317	19	45	28.	320	11	46	0.
165	651116	320	11	47	24.	323	3	48	0.
166	651119	323	3	48	20.	325	19	47	0.
167	651121	325	19	47	18.	328	11	44	0.
168	651124	328	11	45	24.	331	3	44	0.
169	651127	331	3	45	10.	333	19	46	0.
170	651129	333	19	47	0.	336	11	46	0.
172	651205	339	3	46	16.	341	19	45	0.
173	651207	341	19	45	2.	344	11	44	0.
174	651210	344	11	45	59.	347	3	48	0.
175	651213	347	3	48	32.	349	19	49	0.
176	651215	349	19	50	29.	352	11	49	0.
177	651218	352	11	50	36.	355	3	49	0.
181	651229	363	3	54	14.	365	19	53	0.
182	651231	365	19	54	12.	3	11	53	0.
183	660103	3	11	53	39.	6	3	54	0.
184	660106	6	3	54	52.	8	19	57	0.
185	660108	8	19	58	13.	11	12	1	0.
186	660111	11	12	1	32.	14	4	2	0.
187	660114	14	4	2	57.	16	20	1	0.
188	660116	16	20	2	52.	19	12	3	0.
189	660119	19	12	3	22.	22	4	6	0.
190	660122	22	4	6	15.	24	20	9	0.
191	660124	24	20	9	37.	27	12	10	0.
192	660127	27	12	10	44.	30	4	9	0.
193	660130	30	4	10	47.	32	20	11	0.
194	660201	32	20	11	57.	35	12	14	0.
195	660204	35	12	15	15.	38	4	18	0.
196	660207	38	4	19	19.	40	20	20	0.
197	660209	40	20	21	34.	43	12	20	0.
198	660212	43	12	21	49.	46	4	22	0.
199	660215	46	4	22	5.	48	20	23	0.
200	660217	48	20	24	31.	51	12	27	0.

Figure 3. Sample Output Listing

subroutine MILSEC converts seconds of day to hours, minutes, and seconds. The program repeats the above steps for each orbit until it encounters an end of data indicator signifying the end of data on the tape. The program continues by swapping to a new attitude orbit tape by calling the subroutine entry point SWAP. The program terminates after the last attitude orbit tape has been read. The subroutine SWAP swaps to a new tape unit and rewinds the old tape after the swapping. Subroutine SWAP is an entry point in the enclosed listed subroutine READA.

The printed output of the program is listed on consecutively numbered pages. Blank lines are inserted between each tape listing to distinguish orbits covered by each attitude orbit tape.

A flow chart of the main routine READAT is included as Figure 4. A listing of the main program and the subroutines is enclosed as Figures 5 through 8. The format of the OGO attitude orbit tape is given in Figure 9.

IV. CONCLUSIONS

The above described program has been used for the listing of attitude orbit tapes for OGO-I, OGO-II, and OGO-III, and the listed outputs were sent to each OGO experimenter. In the future the program will find further applications for planned OGO missions.

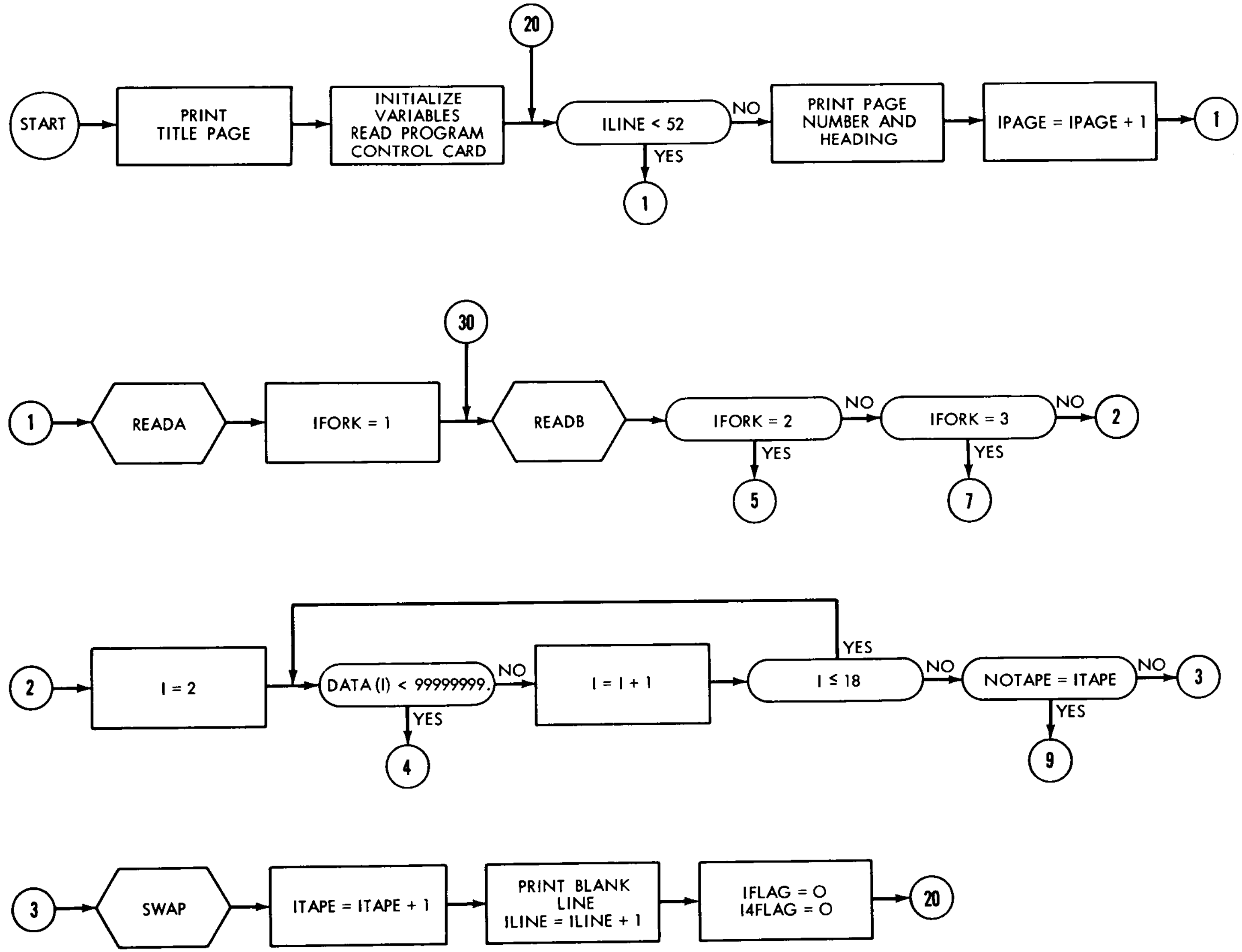


Figure 4A. Flow Diagram of READAT

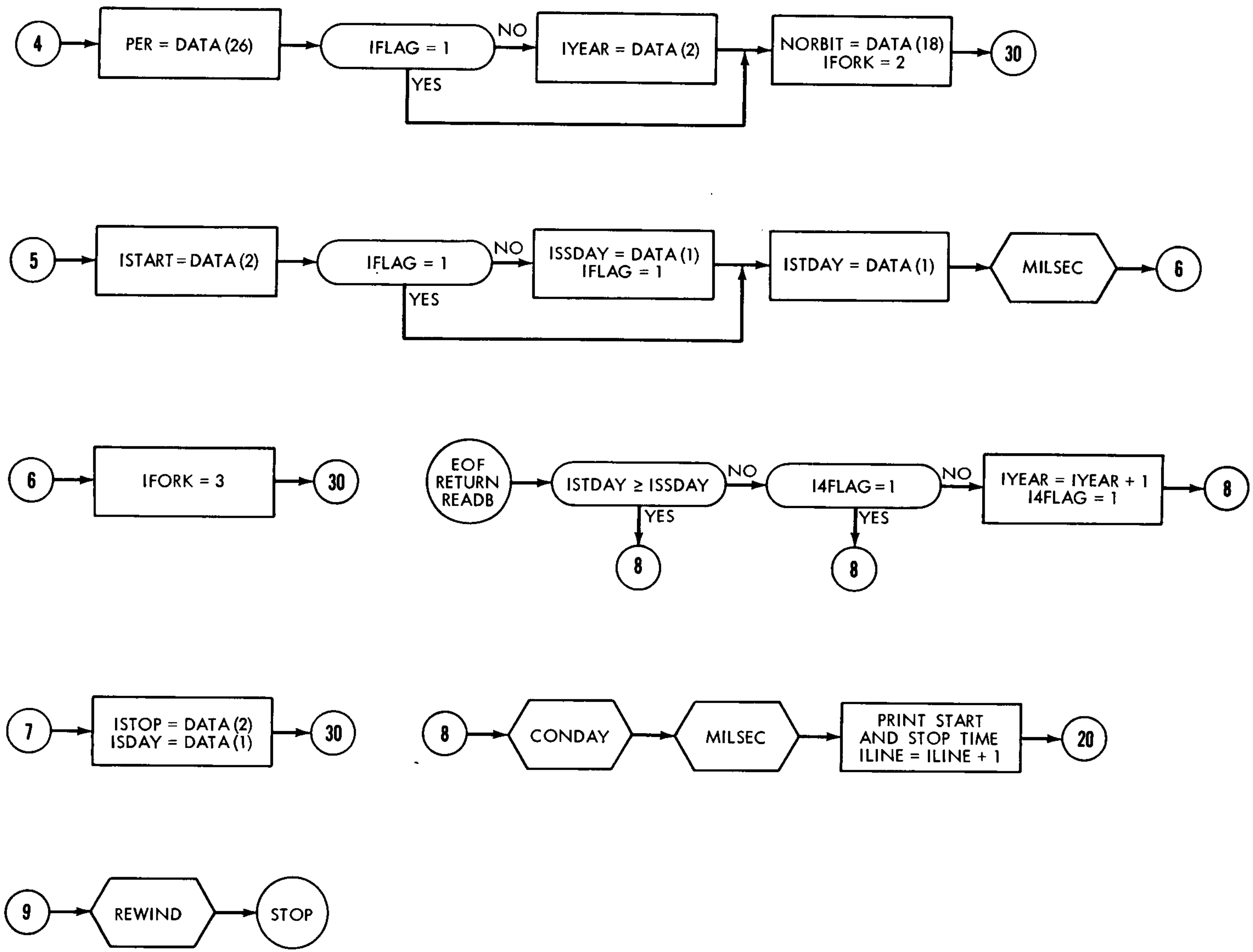


Figure 4B. Flow Diagram of READAT

```
@ ELT READAT,1,670419, 44539

      DIMENSION BUFFER(250),DATA(250)
      PRINT 90
   90 FORMAT(1X//////////////////////////43X,
     1 39H****LISTING OF ATTITUDE ORBIT TAPES****)
      I4FLAG=0
      IFLAG=0
      READ 1,NOTAPE
    1 FORMAT(I5)
      IF (NOTAPE.EQ.0) NOTAPE=1
      IPAGE=1
      ILINE=52
      ITAPE=1
    2 IF (ILINE.LT.52)  GO TO 4
      PRINT 11,IPAGE
   11 FORMAT(5H1PAGE,I3)
      PRINT 12
   12 FORMAT(10H0ORBIT NO.,20X,10HSTART TIME,10X,9HSTOP TIME/15X,
     1 4HDATE,2X,11HDAY OF YEAR,2X,10HHR MIN SEC,5X,14HDAY HR MIN SEC)
      ILINE=3
      IPAGE=IPAGE+1
    4 CALL READA(2,BUFFER,250,-5)
      IFORK=1
    3 CALL READB(NOREC,DATA,$100,$200)
      GO TO (10,20,30) ,IFORK
   10 DO 5 I=2,18
      IF (DATA(I).LT.99999999.)  GO TO 8
    5 CONTINUE
```

Figure 5A. Listing of Main Program READAT

```
      IF (NOTAPE.EQ.ITAPE)  GO TO 500
      CALL SWAP(2)
      ITAPE=ITAPE+1
      PRINT 50
   50 FORMAT(1H )
      ILINE=ILINE+1
      IFLAG=0
      I4FLAG=0
      GO TO 2
    8 PER=DATA(26)
      IF (IFLAG.EQ.1)  GO TO 9
      IYEAR=DATA(2)
    9 NORBIT=DATA(18)
      IFORK=2
      GO TO 3
   20 ISTART=DATA(2)+0.5
      IF (IFLAG.EQ.1)  GO TO 21
      ISSDAY=DATA(1)
      IFLAG=1
   21 ISTDAY=DATA(1)
      CALL MILSEC(ISTART,DUM,IHOUR,IMIN,SEC)
      IFORK=3
      GO TO 3
   30 ISTOP=DATA(2)+0.5
      ISDAY=DATA(1)
      GO TO 3
  100 IF (ISTDAY.GE.ISSDAY)  GO TO 45
      IF (I4FLAG.EQ.1)  GO TO 45
      IYEAR=IYEAR+1
```

Figure 5B. Listing of Main Program READAT

```
      I4FLAG=1
   45 CALL CONDAY(IYEAR,ISTDAY,DATE1)
   46 CALL MILSEC( ISTOP,DUM,IHOURS,IMINS,SECS)
      PRINT 35,NORBIT,DATE1,ISTDAY,IHOUR,IMIN,SEC,ISDAY,IHOURS,
     1 IMINS,SECS
   35 FORMAT(1X,I5,8X,A6 ,5X,I3,5X,I2,I4,F5.0,5X,2I3,I4,F5.0,1X,F12.2)
      ILINE=ILINE+1
      GO TO 2
  200 PRINT 201
  201 FORMAT(29H1***TAPE READ ERROR RETURN***)
  500 REWIND 2
      CALL EXIT
      END
```

Figure 5C. Listing of Main Program READAT

```
@ ELT CONDAY,1,661219, 47487

                                 . THIS SUBROUTINE CONVERTS THE DAY OF YEAR TO A DATE
                                 . OR CONVERSELY CONVERTING THE DATE TO THE DAY OF YEAR
                                 . DEPENDING ON THE ENTRY POINT. THE DATE IS IN FIELDATA
                                 . FORMAT AND IS CONTAINED IN ONE WORD. THE CHARACTERS
                                 . OF THE WORD ARE ASSIGNED AS FOLLOWS, YYMMDD.
                                 . AN EXAMPLE PRINTED OUT WOULD APPEAR LIKE 661015
                                 .     TO CONVERT THE DAY OF YEAR AND YEAR TO A DATE THE
                                 . SUBROUTINE IS CALLED WITHE FOLLOWING CALL STATEMENT
                                 .  CONDAY (NYEAR,NDAY,DATE)
                                 . NYEAR SHOULD BE AN INTEGER AND CAN BE E.G., 66 OR 1966
                                 . NDAY  SHOULD BE AN INTEGER
                                 . DATE IS RETURNED IN FIELDATA FORMAT, WHEN PRINTED OUT
                                 . LOOKS LIKE THIS 661015 AS AN EXAMPLE
                                 . IF THE DAY OF YEAR IS GREATER THAN 366 THE DAY RETURNED
                                 . WILL BE 0. NO PROVISIONS ARE MADE FOR NEGATIVE NUMBERS.
                                 .
                                 .     TO CONVERT THE DATE IN FIELDATA TO THE DAY OF YEAR
                                 . AND YEAR THE SUBROUTINE IS CALLED WITH THE STATEMENT
                                 .  CONDAT (DATE,NYEAR,NDAY)
                                 . THE SAME CONDITIONS APPLY TO THE ARGUMENTS AS DEFINED ABOVE
                                 . HENRY LINDER, CODE 565, 12/8/66.
                CONDAY*  L,14    12,28
                         S       12,A+1         . THIS SETS 28 DAYS FOR FEBRUARY
                         L       12,*0,11       . LOAD YEAR
                         JB      12,SKIP        . TEST FOR LEAP YEAR
                         SSA     12,1
                         JB      12,SKIP
```

Figure 6A. Listing of Subroutine CONDAY

```
                L,14    12,29           . FEBRUARY HAS 29 DAYS
                S       12,A+1          . STORE IN A+1
        SKIP    L       12,(1,0)
                L       15,*1,11        . DAY OF YEAR INTO 15
                TG,14   15,367
                L,14    15,0            . IF DAY IS GREATER THAN 366 MAKE IT 0
        LOOP    ANA     15,A,*12
                JN      15,FINI
                JNZ     15,LOOP
        FINI    A       15,A-1,12
                L,14    14,0            . CLEAR 14 FOR DIVISION
                DI,14   14,10           . DIVIDE BY 10
                S,9     14,DATE         . TENS ARE IN 14
                S,8     15,DATE         . ONES ARE IN 15
                AND     12,(0,0777777)
                L,14    12,0            . NOW GET THE MONTH
                DI,14   12,10           . MONTH IS IN 13
                S,11    12,DATE         . TENS ARE IN 12
                S,10    13,DATE         . ONES ARE IN 13
                L       15,*0,11        . LOAD YEAR FOR CONVERSION
                TG,14   15,100          . TEST FOR YEAR, E.G.,66 OR 1966
                ANA,14  15,1900
                L,14    14,0
                DI,14   14,10
                S,13    14,DATE         . TENS ARE IN 14
                S,12    15,DATE         . ONES ARE IN 15
                L       17,DATE
                OR      17,(0606060606060)      . MAKE IT FIELDATA
                S       18,*2,11        . STORE IN THIRD ARGUMENT
```

Figure 6B. Listing of Subroutine CONDAY

```
        J      3,11
CONDAT* L,14   12,28
        S      12,A+1          . THIS SETS 28 DAYS FOR FEBRUARY
        L      12,*0,11        . GET DATE AS INPUT
        AND    12,(0171717171717)
        S      13,DATE
        L,13   12,DATE
        MSI,14 12,10
        A,12    12,DATE        . YEAR IS IN 12
        S      12,*1,11        . STORE IN SECOND ARGUMENT
        JB     12,SKIP2        . TEST FOR LEAP YEAR
        SSA    12,1
        JB     12,SKIP2
        L,14   12,29           . FEBRUARY HAS 29 DAYS
        S      12,A+1          . STORE IN A+1
SKIP2   L,11   12,DATE         . GET THE MONTH
        MSI,14 12,10
        A,10    12,DATE
        AN,14   12,1
        L,9    15,DATE         . GET THE DAY OF MONTH
        MSI,14 15,10
        AA,8   15,DATE
        J      BEG
LOOP2   AA     15,A,12
BEG     JGD    12,LOOP2
        S      15,*2,11        . THE DAY OF YEAR IS IN 15
        J      3,11
$(1)
A       +31                    . JANUARY
```

Figure 6C. Listing of Subroutine CONDAY

```
000086            +28       . FEBRUARY
000087            +31       . MARCH
000088            +30       . APRIL
000089            +31       . MAY
000090            +30       . JUNE
000091            +31       . JULY
000092            +31       . AUGUST
000093            +30       . SEPTEMBER
000094            +31       . OCTOBER
000095            +30       . NOVEMBER
000096            +31       . DECEMBER
000097   DATE     RES  1
000098            END
```

Figure 6D. Listing of Subroutine CONDAY

```
@ ELT MILSEC,1,670419, 44542

MILSEC* L      13,*0,11
        L,14   12,0
        DI     12,(86400000)
        S      12,*1,11    DAYS IN 12
        L,14   12,0
        DI     12,(3600000)
        S      12,*2,11
        L,14   12,0
        DI     12,(60000)
        S      12,*3,11
        L,14   14,155
        LCF    14,13
        FM     15,(1.000000*-03)   SEC IN 15
        S      15,*4,11
        J      6,11
        END
```

Figure 7. Listing of Subroutine MILSEC

```
@ ELT READA,1,670419, 44541

R1   EQU  0101
R2    EQU 0102
R3   EQU  0103
B11 EQU  11
A0   EQU  12
A1   EQU  13
A2   EQU  14
A3   EQU  15
A4   EQU  16
A5   EQU  17
S1    EQU 015
S2    EQU 014
H1    EQU 2
H2    EQU 1
M     EQU 14
$(1).
READA*  L       R3,NMNP
        L       A3,*0,B11       UNIT NUMBER
        L       A4,*3,B11       BUFFER FLAG
         S     A4,BFLAG
        L       A3,NTAB$,A3     LOGICAL UNIT
        TNG,M   A3,6
        J       ERRR2
        JZ      A4,RDNT         NOT BUFFERED
        S,H2    A3,CSTA
        L,M     A4,*1,B11       BUFFER ADDRESS
        S,H2    A4,XW1
```

Figure 8A. Listing of Subroutine READA

```
                S,H2    A4,ACSS
                L       A4,*2,B11       BUFFER SIZE
                S,H1    A4,ACSS
                L,M     A5,5,B11
                S,H2    A5,EXIT
        TAPR    L,M     A4,2            SAY TRANSMITTING
                S,S1    A4,STB
                LMJ     B11,TRF$        INITIATE TRANSFER
        CSTA    +       ENDA,$-$
        ACSS    +       $-$,$-$
        EXIT    J       $-$
        ENDA    SZ,S1   STB             SAY BUFFER READY
                S,S2    A0,STB          SAVE STATUS REPORT
                SSL     A1,18
                AN,H1   A1,ACSS         COMPUTE N(WORDS READ)
                SNA,H2  A1,STB
                J       0,B11
        ERRR2   SLJ     NERR$
                +       4
        READB*  L       R3,NMN
                L,M     A5,5,B11
                S,H2    A5,EXIT
                TNZ,H2  CSTA
                J       RDNW            NOT BUFFERED
               TZ,S1   STB
               J       $-1
                TZ,S2   STB
                J       EXCP            STATUS-EXCEPTION
        DATA     L,M   A2,*1,B11
```

Figure 8B. Listing of Subroutine READA

```
                 A        A2,XNCR
                 L        A1,XW1            BUFFER LOC
                 L,H2     R1,STB            COUNT
                 S        R1,*0,B11
                 BT       A2,0,*A1          INPUT FROM BUFFER
                 J        TAPR              READ NEXT
        EXCP     L,S2     A0,STB            STATUS CODE
                 TE,M     A0,2
                 J        ERRR3
        ABNM     LN       A0,A0             END OF FILE
                 S        A0,*0,B11
                J        2,B11          . JUMP TO EOF EXIT, ARG. 3 IN READB
        ERRR3     L,M     A3,3,B11
                  S,H2    A3,EXIT3
                  S       A2,TSTAT
                  L,S1    A2,TSTAT
                  TE,14   A2,044
                  J       C1
                  P$RINT  MESG1,5,60
                  J       SWITCH
        C1        TE,14   A2,060        END OF TAPE OR LOAD POINT
                  J       C2
                  P$RINT  MESG2,5,60
                L         12,(-500)
                  S       12,*0,11
                  J       EXIT3         NO RECOVERY
        C2        TE,14   A2,065
                  J       C3
                  P$RINT  MESG3,3,60
```

Figure 8C. Listing of Subroutine READA

```
                J       SWITCH
        C3      TE,14 A2,070
                J       C4
                L,8     A4,TSTAT
                AND,14  A4,010
                JZ      A5,CC1
                P$RINT MESG4,10,60
                J       DATA            TEMPORARY CONTINUATION
        EXIT3   J       $-$
        C4      P$RINT MESG7,8,100
                S       A2,MESG8
                P$RINT    MESG8,1,10
                J       SWITCH
        CC1     J       DATA            TEMPORARY CONTINUATION
        SWITCH  TN      BFLAG
                J       DATA            ACCEPT BLOCK AS IS
                P$RINT MESG6,9,60
                L,H2    A5,EXIT
                S,H2    A5,BFLAG
                L,14    A5,DETCUR
                S,H2    A5,EXIT
                J       TAPR
        DETOUR  L,H2    A5,BFLAG
                S,H2    A5,EXIT
                J       READB
         UNT    S,H2      A3,CSTB           READ NOT BUFFERED
                S,H2      A3,CSTC
                SZ,H2     CSTA
                L         A4,*2,B11         SET NMAX
```

Figure 8D. Listing of Subroutine READA

```
                S,H1    A4,ACSB
                J       5,B11
        RDNW    L,M     A4,*1,B11          LOC(DATA)
                S,H2    A4,ACSB
                L,M     A4,*0,B11          LOC(COUNT)
                S,H2    A4,STCT
                LMJ     B11,TRF$           READ
        CSTB    +       0,$-$
        ACSB    +       $-$,$-$
                LMJ     B11,TCHK$          CHECK
        CSTC    +       ERRR,$-$
                +       ABNM,$-2
                SSL     A1,18              COMPUTE COUNT
                AN,H1   A1,ACSB
        STCT    SNA     A1,$-$
                J       EXIT
        ERRR    L       R3,NMN             ERROR
                L,H2    B11,EXIT
                AN,M    B11,1
                SLJ     NERR$              ERROR EXIT
                +       0
        NMNP    'READA'
        NMN     'READB'
        $(2).
        TSTAT    RES    1
        BFLAG    RES    1
        XNCR    +       01000000
        XW1     +       1,$-$
        STB     RES     1
```

Figure 8E. Listing of Subroutine READA

```
MESG1    'PARITY ERROR IN TAPE BLOCK'
MESG2    'LOAD POINT OR END OF TAPE'
MESG3    'TAPE HASH IN BLOCK'
MESG4    'CHARACTER COUNT TO BE IGNORED, ANOTHER ATTEMPT WILL BE MADE'
MESG5    'CHARACTER COUNT ERROR IN TAPE BLOCK'
MESG6    'DATA BLOCK WILL BE DICARDED, NEXT BLOCK WILL BE READ'
MESG7    'UNDEFINED ERROR IN TAPE BLOCK,TAPE STATUS IS'
MESG8     +      0
SWAP*    L,14   12,2,11
         S,1    12,EXIT2
         L      12,*0,11
         L      13,NTAB$,12
         S,1    13,CSTD
         LMJ    11,TSWAP$
CSTD     +      0,$-$
EXIT2    J      $-$
         END.
```

Figure 8F. Listing of Subroutine READA

ATTITUDE-ORBIT TAPE FORMAT

All data is represented in floating point format:

left 9 bits	characteristic
right 27 bits	mantissa

There is one orbit per file. After the EOF following the last data record, there is a (250 word) record of floating point nines, i.e., 99999999.0, which is followed by an EOF. Orbit 1 starts at the first ascending node after launch. All attitude-orbit tapes have odd parity.

Attitude-Orbit Label Record				
Word	**Symbol**	**Function or Name**	**Description, Notes**	**Units**
1	ID	Identification		none
2 3 4		Start time of orbit	Greenwich Mean Time (GMT) is used. This is also called Universal Time.	year month day
5 6	tE1	Eclipse start	Start time of eclipse in GMT.	day millisec of day
7 8	tE2	Eclipse end	End time of eclipse in GMT	day millisec of day
9 10	tO1	Orbit start	Start time of orbit. That is, time of the ascending node. The ascending node is that point in the equatorial plane through which the satellite passes while going from south to north. See Figure (c).	day millisec of day

Figure 9. Attitude-Orbit Tape Format and Definitions

Word	Symbol	Function or Name	Description, Notes	Units
11 12	tO2	Orbit end	End time in GMT of this orbit and start time of the next orbit. That is, time of the next ascending node. See Figure (c).	day millisec of day
13 14	tn	Noon turn	Time in GMT of predicted noon turn. The paddles are only able to rotate through 180°. When the paddles are looking straight up (φ_p = 270°) or straight down (φ_p = 90°) at the sun, the spacecraft turns 180° about the body Z axis, so the paddle may reverse its direction of rotation and still continue to follow the sun. See data record word 121.	day millisec of day
15 16	τ	Epoch	The arbitrary reference time in GMT at which the orbital elements were computed.	day millisec of day
17	Δt	Sampling rate	The values in the data records are given at intervals of $t_a + \Delta t$. The value of Δt is expected to be 60,000 milliseconds (1 min).	milliseconds
18		Orbit number	Orbit zero is from launch to the first ascending node. Orbit one starts at the first ascending node	none

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
			and ends at the second ascending node. The n^{th} orbit starts at the n^{th} ascending node. See Figure (c).	
19	a	Semi-major axis	The semi-major axis of the orbital ellipse (1 Earth radius = 6378.388 km). See Figure (a).	earth radii
20	e	Eccentricity	The eccentricity of the orbital ellipse. See Figure (a).	none
21	i	Inclination	The angle of the orbital plane and the earth's equatorial plane. See Figure (b).	degrees
22	Ω	Longitude of ascending node	The angle between the Geocentric Equatorial Inertial (GEI) X axis (♈) and the position vector of the ascending node. See Figure (d).	degrees
23	$\dot{\Omega}$		Rate of change of Ω.	degrees/day
24	ω	Argument of perigee	Perigee is that orbital point which is nearest the earth. ω is the angle between the position vector of the ascending node and the position vector of perigee. See Figure (c).	degrees
25	$\dot{\omega}$		Rate of change of ω.	degrees/day

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
26	T	Period	The time required to make one orbit.	minutes
27	$\dot{T}$		Rate of change of T.	minutes/day
28-99			Spares	
100	r	Spin rate	If the spacecraft is spinning about an axis which is stabilized with respect to the craft, the spin rate, r, is given as a positive number.	degree/sec
101	$\dot{r}$		Rate of change of r	degrees/sec/ day
102-104	A	GEI spin axis	A = (Ax, Ay, Az) and is the spin axis as a unit vector in GEI coordinates A is defined so the spin rate, r, is positive with respect to the right-hand rule	none
105-107	Ab	Body spin axis	Ab = (Abx, Aby, Abz) is the spin axis as a unit vector represented in body coordinates. This representation will not change when the spin axis is stabilized with respect to the spacecraft.	none
108-116	R1	First spin matrix	In each of R1, R2, and R3, the first three words contain the values in the top	none

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
			σ (T) is the angle from the spin vector $A(T_1) = (Ax, Ay, Az)$ at time T_1 to spin vector A(T) at time T. See Application 3 in Appendix B for more details.	
135-250			Spares	
Attitude-Orbit Data Record				
1	T1	Time	Day count.	days
2			Milliseconds of day in Greenwich Mean Time (GMT). All data in this record corresponds to T_1.	milliseconds
3 4 5	TL	Local Time	Local Apparent Solar Time of subsatellite point.	hours minutes tenths of minutes
6	α	Right ascension	The angle from the first point of Aries (♈) to the equatorial plane projection of the spacecraft position vector. See Figure (e).	degrees
7	δ	Declination	The angle from the equatorial plane projection of the spacecraft position vector to the	degrees

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
117-125	R2	Second spin matrix	row of the matrix, the second three words contain the values in the middle row of the matrix, and the last three words contain the bottom row of the matrix.	
126-134	R3	Third spin matrix	Let: $$b(T_1) = \begin{bmatrix} bXx & bYx & bZx \\ bXy & bYy & bZy \\ bXz & bYz & bZz \end{bmatrix}$$ where bXx through bZz are defined in data record words 49-57, i.e., bx, by, and bz at T_1 where T_1 is defined in word 1 of the data record. Now let $\bar{b}(T)$ be the interpolation of $b(T_1)$ to time T with no correlation for spin. Then: $$b(T) = \bar{b}(T)\ R1 + \bar{b}(T)\ R2 \sin \sigma (T) + b(T)\ R2 \cos \sigma (T) = \bar{b}(T) \mid R1 + R2 \sin \sigma (T) + R3 \cos \sigma T \mid$$ where b(T) defines the body coordinate axes in GEI coordinates, as in $b(T_1)$, and	

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
			spacecraft position vector. See Figure (e).	
8,9, 10	P	Position vector	P = (Px, Py, Pz) is the position vector of the spacecraft in Geocentric Equatorial Inertial (GEI) coordinates. GEI co-ordinates are also known as Universal coordinates. See Figure (e).	kilometers
11,12, 13	V	Velocity vector	V = (Vx, Vy, Vz) is the direction and magnitude of the spacecraft velocity in GEI coordinates. See Figure (e).	kilometers/ sec
14,15, 16	S	Solar vector	S = (Sx, Sy, Sz) is the position vector of the sun in GEI coordinates.	kilometers
17	φ	Latitude	Geodetic latitude of sub-satellite point on the spheroid. North is +, South is –. The International Spheroid is used: a = semi-major axis = 6378.388 km f = flattening = 297. = a/a-b.	degrees
18	λ	Longitude	Geodetic longitude of sub-satellite point on the spheroid. East is +, West is –.	degrees

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

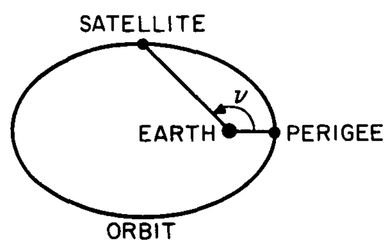
Word	Symbol	Function or Name	Description, Notes	Units
19	h	Height	Height of satellite above the spheroid. See Figure (e).	kilometers
20	ν	True anomaly	Orbital central angle between perigee and satellite with earth as focus. See Figure (a).  	degrees
21	Φ	Sun earth satellite angle	The angle between the satellite position vector and the sun position vector.	degrees
22,23, 24	bXI	Ideal body roll axis	bXI = (bXIx, bXIy, bXIz) is the ideal body X axis as a unit vector in GEI coordinates.	none
25,26, 27	bYI	Ideal body pitch axis	bYI = (bYIx, bYIy, bXIz) is the ideal body Y axis as a unit vector in GEI coordinates.	none
28,29, 30	bZI	Ideal body yaw axis	bZI = (bZIx, bZIy, bZIz) is the ideal body Z axis as a unit vector in GEI coordinates.	none

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
31,32 33	PXI	Ideal paddle roll axis	PXI = (PXIx, PXIy, PXIz) is the paddle X axis as a unit vector in GEI coordinates	none
34,35 36	PYI	Ideal paddle pitch axis	PYI = (PYIx, PYIy, PYIz) is the paddle Y axis as a unit vector in GEI coordinates.	none
37,38 39	PZI	Ideal paddle yaw axis	PZI = (PZIx, PZIy, PZIz) is the paddle Z axis as a unit vector in GEI coordinates.	none
40,41 42	EXI	OPEP ideal roll axis	EXI = (EXIx, EXIy, EXIz) is the OPEP X axis as a unit vector in GEI coordinates.	none
43,44 45	EYI	OPEP ideal pitch axis	EYI = (EYIx, EYIy, EYIz) is the OPEP Y axis as a unit vector in GEI coordinates.	none
46,47 48	EZI	OPEP ideal yaw axis	EZI = (EZIx, EZIy, EZIz) is the OPEP Z axis as a unit vector in GEI coordinates.	none
49,50 51	bX	Actual body roll axis	bX = (bXx, bXy, bXz) is the body X axis as a unit vector in GEI coordinates.	none
52,53 54	bY	Actual body pitch axis	bY = (bYx, bYy, bYz) is the body Y axis as a unit vector in GEI coordinates.	none

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
55,56 57	bZ	Actual body yaw axis	bZ = (bZx, bZy, bZz) is the body Z axis as a unit vector in GEI coordinates.	none
58,59 60	PX	Actual paddle roll axis	PX = (PXx, PXy, PXz) is the paddle X axis as a unit vector in GEI co-ordinates.	none
61,62 63	PY	Actual paddle pitch axis	PY = (PYx, PYy, PYz) is the paddle Y axis as a unit vector in GEI co-ordinates.	none
64,65 66	PZ	Actual paddle yaw axis	PZ = (PZx, PZy, PZz) is the paddle Z axis as a unit vector in GEI co-ordinates.	none
67,68 69	EX	Actual OPEP roll axis	EX = (EXx, EXy, EXz) is the OPEP X axis as a unit vector in GEI co-ordinates.	none
70,71 72	EY	Actual OPEP pitch axis	EY = (EYx, EYy, EYz) is the OPEP Y axis as a unit vector in GEI co-ordinates.	none
73,74 75	EZ	Actual OPEP yaw axis	EZ = (EZx, EZy, EZz) is the OPEP Z axis as a unit vector in GEI co-ordinates.	none
76	R	Magnetic range	$R = L \cos^2 (\varphi m)$ where L is the McIlwain parameter of the magnetic shell containing the spacecraft, and	earth radii

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

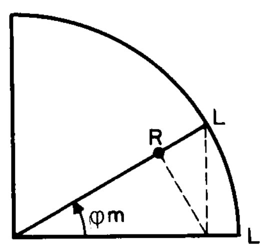
Word	Symbol	Function or Name	Description, Notes	Units
			φ m is the magnetic latitude of the spacecraft. Note that R is analogous to, but not equal to, $\lvert P \rvert$, the magnitude of the position vector.	
77	φ m	Magnetic latitude	The latitude of the spacecraft in geomagnetic coordinates. At the magnetic equator $\varphi m = 0$. See Figure (f).	degrees
			 RELATIONSHIP BETWEEN L AND R	
78	L	McIlwain parameter	A magnetic shell parameter which is almost constant along lines of force. L is used to label each shell. Note that in the ideal case (dipole field), L is the magnitude of the position vector on the magnetic equator of the line of force. See Figure (f).	earth radii
79	B	Field strength	The magnitude of magnetic field strength at	gamma

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
			the spacecraft. See Figure (c).	
80	B/B_0	Ratio	B is defined above. B_0 is the equatorial field strength of the shell. See Figure (f).	none
81	φI	Ingress latitude	The latitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft enters the earth. See Figure (f).	degrees
82	λI	Ingress longitude	The longitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft enters the earth. See Figure (f).	degrees
83	φE	Egress latitude	The latitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft leaves the earth. See Figure (f).	degrees
84	λE	Egress longitude	The longitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft leaves the earth. See Figure (f).	degrees

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
85,86, 87	$\hat{B}$	B vector	$\hat{B}$ = (Bx, By, Bz) is the direction of the magnetic line of force expressed as a unit vector in the GEI system.	none
88,89, 90	Bb	B Body	Bb = (Bbx, Bby, Bbz) is the unit direction vector, $\hat{B}$, expressed in the body coordinate system.	none
91,92, 93	BP	B Paddle	BP = (BPx, BPy, BPz) is the unit direction vector, $\hat{B}$, expressed in the paddle coordinate system.	none
94,95, 96	BE	B OPEP	BE = (BEx, BEy, BEz) is the unit direction vector, $\hat{B}$, expressed in the OPEP coordinate system.	none
97,98, 99	B$\hat{B}$G	B$\hat{B}$ geodetic	B$\hat{B}$G is the product of the field strength, B, times the unit vector, $\hat{B}$G = ($\hat{B}$GE, $\hat{B}$GN, $\hat{B}$GV), where ($\hat{B}$GE, $\hat{B}$GN, $\hat{B}$GV) is the unit vector, $\hat{B}$, expressed in geodetic coordinates. Note that this is a left-handed system instead of a right-handed system.	

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
100-108	TGSE	GSE transformation	This is the transformation matrix which changes the GEI representation of a vector to GSE (Geocentric Solar Ecliptic) representation. The vector remains fixed. Words 100, 101, and 102 contain the values for the top row of the matrix, words 103, 104, and 105 contain the values for the middle row of the matrix, and words 106, 107, and 108 contain the values of the bottom row of the matrix. Any vector, v, in GEI is transformed by the relation $v_{GSE} = (\text{matrix})\, v_{GEI} = \text{TGSE}\, v_{GEI}$	none
109-117	TGSM	GSM transformation	This is the transformation matrix which changes the GEI representation of a vector to GSM (Geocentric Solar Magnetic) representation. The vector remains fixed. Words 109, 110, and 111 contain the top row of the matrix, words 112, 113, and 114 contain middle row of the matrix, and words 115, 116 and 117 contain the bottom row of the matrix.	none

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
118-120	A	GEI spin axis	A = (Ax, Ay, Az) is the unit spin axis in GEI coordinates.	none
121	φP	Paddle angle	The paddle shaft angle is $\varphi P = 90°$ when the paddle is looking in the direction of the body +Z axis (toward earth), it is $\varphi_p = 180°$ when the paddle is looking in the -Y body axis direction (away from the OPEP), and $\varphi P = 270°$ when the paddle is looking in the body -Z direction (away from the earth). Movement of the paddle is restricted such that $90° \leq \varphi_p \leq 180°$	
122	ΨE	OPEP angle	The OPEP shaft angle is $\Psi E = 0$ when the OPEP is looking in the body +X direction (away from the spacecraft), and $\Psi E = 90°$ when the OPEP is looking in the body +Y direction (away from the spacecraft), and $\Psi E = 270°$ when the OPEP is looking in the body -Y direction (looking over the spacecraft). The OPEP can rotate through more than 360°	degrees

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
123	none	Attitude data flag	This flag is assigned the floating point value -1.0 if any housekeeping discrepancies are detected.	none
124	none	NO DATA flag	A value of 2^K or any combination of $2^{K1} \cdot 2^{K2} \ldots 2^{K5}$ in the NO DATA flag signifies that the data indicated by the flag was not available. The ideal value is used when the actual value is not available. The following table is used in words 124 and 125: bit value — data 2^0 roll 2^1 pitch 2^2 yaw 2^3 ΨE = OPEP shaft angle 2^4 φP = Paddle shaft angle 2^5 Array error (Note that word 124 is floating point.)	
125	none	SUSPECT DATA flag	This word warns that the indicated data is of a suspected nature. The indica-	none

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)

Word	Symbol	Function or Name	Description, Notes	Units
			tions are the same as for word 124.	
126	T2	Time	T2 = T1 + Δt and is defined the same as T1.	none
127-250			Defined the same as words 2-125 except that time T2 is used.	none

Abbreviations

EOF	End of File
GEI	Geocentric Equatorial Inertial (coordinates)
GMT	Greenwich Mean Time
GSE	Geocentric Solar Equatorial
GSM	Geocentric Solar Magnetic

Figure 9. Attitude-Orbit Tape Format and Definitions (Continued)